THE INFLUENCE OF PHYSIOLOGICAL PHENOMENA ON VISUAL OBSERVATIONS OF THE SPECTRUM OF THE NEBULÆ.

By JAMES E. KEELER.

According to the view almost universally accepted by astrophysicists, the stars have been evolved from pre-existing nebulæ by a gradual process of condensation. The view is an old one; but before the spectroscope was invented, it was necessarily based on very simple data, derived from observations of the forms of nebulæ as seen in the telescope. The spectroscope opened up an entirely new method of attack. Used in connection with the great telescopes of modern times it has furnished an immense mass of data, and the study of the different types of stellar spectra and their probable connection with the order of stellar evolution has become an exceedingly complicated and interesting branch of astronomical science.

In a general way, it may be said that the evidence brought to light by the spectroscope is in harmony with the views which had already been held, though it would not be difficult to point out numerous difficulties and contradictions. As the spectrum of the nebulæ is regarded as the signature of the earliest stage of stellar evolution, it is not surprising that astrophysicists have attached special importance to it in their studies, and that they view every discovery or investigation relating to it with the greatest interest.

A discussion has recently been carried on in the *Astrophysical Journal* and the *Astronomische Nachrichten*, with reference to the part played by physiological causes in visual observations of the bright lines in nebular spectra. The spectrum of a nebula contains many bright lines, most of which are, however, very faint, and are revealed by long-exposure photographs only. Ordinarily only a few lines are seen—one at λ 5007, (the "chief" nebular line), one at λ 4959, probably due to the same unknown substance as the preceding, and in addition to these, some of the lines of hydrogen and helium. Some years ago, Professor CAMPBELL, while observing the Great Nebula of *Orion* with the thirty-six inch telescope, found that the spectrum was different in different regions. In the central and brighter parts of the nebula, the greenish-blue hydrogen line F, or $H\beta$, was about as bright as the

second nebular line λ 4959. In the faint and remote region surrounding the star *Bond* 734, all the lines were of course faint, but the Hβ line was at least five times brighter than even the chief nebular line, while the second line was quite invisible.

These observations of Professor CAMPBELL (which have been confirmed by various members of the Lick Observatory staff, and by the eminent spectrocopist, Professor RUNGE of Hanover, Germany, while on a visit to Mt. Hamilton) were regarded by him as indicating a real difference in the distribution of the materials of which the nebula is composed. The substance, whatever it may be, which gives the principal lines in the green, is more strongly concentrated in the central regions of the nebula; in the faint and remote regions, hydrogen is predominant. In a previous number of these *Publications*,* I have pointed out the fact that these differences of distribution of the substances in the nebula (assuming them to be real), must lead to a difference between the forms of the nebula as shown in drawings and in photographs.

Professor SCHEINER, of the Astrophysical Observatory at Potsdam, holds, on the contrary, that the spectrum of the *Orion* nebula is the same in all its parts, and attributes the differences observed by Professor CAMPBELL to physiological causes. By what is known as the "Purkinje effect," the maximum of brightness in the spectrum shifts toward the violet end when the intensity of the light is diminished. If, therefore, we suppose that two lines, one red and one blue, are equally bright when the intensity of the illumination has a certain value, the red line will appear brighter than the blue if the intensity is increased, and the blue line will appear brighter than the red if the intensity is diminished. The blue line may even be distinctly seen after the red line has faded into invisibility.

In Professor SCHEINER'S opinion, the observations of Professor CAMPBELL are sufficiently explained by this physiological effect, as well as the fact that the red hydrogen line C or Hα has been observed in very few nebulæ. His views were confirmed by some photometric observations which he made on the artificial spectrum of hydrogen.

In connection with these observations, Professor SCHEINER, extending some earlier researches of KOCH, made some experiments in which he sought to ascertain the possible influence on

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the spectrum of the temperature of the surroundings under which hydrogen emits light. The hydrogen was enclosed in a vessel which was cooled down to a temperature of — 200° C. by means of liquid air, and it was made luminous by extremely feeble electric waves. The temperature of the hydrogen under these conditions approached the absolute zero — 273° C., but its spectrum was the same as that observed at ordinary temperatures. Hence, there seems to be no reason to suppose that the spectrum of hydrogen in the nebulæ is influenced by the cold of surrounding space.

It will be seen that the apparent shifting of the brightness in the spectrum, due to the Purkinje effect, is in the right *direction* to explain the observations of Professor CAMPBELL on physiological grounds, since these observations showed that the more refrangible line was relatively brighter in the faint regions of the nebula. In my opinion, however, the Purkinje effect is inadequate to explain the *amount* of the observed variations of brightness. Professor SCHEINER'S experiments dealt with an extreme case. The lines compared ($H\alpha$ and $H\beta$) were widely separated, and the physiological effect was strongly marked. But in Professor CAMPBELL'S observations, verified by Professor RUNGE, the lines compared were in nearly the same spectral region, so that the physiological effect must have been very much smaller; yet the variation of the relative brightness of the lines was from twenty to thirty-fold. It is difficult to avoid the conclusion that we are here dealing with actual differences in the radiation from different regions of the nebula.

When the *Orion* nebula again comes into position for observation with the great telescope, it will be easy to make an experiment in which physiological effects are wholly eliminated. With the spectroscope slit placed on the bright region near the trapezium, the intensity of the light can be diminished (say by reducing the vertical aperture of the spectroscope) until the second nebular line (λ 4959) is barely visible, or about as bright as it is with full aperture in some remote region of the nebula. Under these circumstances, any considerable differences in the relative brightness of the $H\beta$ line could not be ascribed to physiological causes. Photography could perhaps be made to furnish a still more satisfactory test.

I am further not quite convinced that the invisibility of the $H\alpha$ line in the spectrum of the great majority of nebulæ is entirely

due to the Purkinje effect. It is easy enough to reduce the visible hydrogen spectrum, derived from spectrum tubes, to the single line $H\beta$, by merely diminishing its brightness; but to my eye, at least, $H\gamma$ always disappears before $H\alpha$. In the nebulæ, on the other hand, $H\gamma$ is seen without difficulty, while $H\alpha$ is generally invisible. In some stars we find hydrogen exhibiting certain spectral peculiarities which have not yet been produced artificially, and certainly there is nothing absurd in the supposition that hydrogen in the nebulæ can have a spectrum which differs in some respects from that obtained in our laboratories. The difference, if it is real, as I believe it to be, may be a key which will finally unlock some of the many mysteries by which the nature and constitution of the nebulæ are still surrounded.

WOLF'S PERIODICAL COMET.

By W. J. Hussey.

On the night of June 16th, I turned the 36-inch refractor to the place given by THRAEN's ephemeris of WOLF's periodical comet (*Astronomische Nachrichten*, No. 3484), and at once found it at less than its own diameter from its predicted place. My observation at the time of rediscovery gives the following position, which is already corrected for parallax and aberration:—

Greenwich M. T.	True α	True δ
1898 June 16.95449	$2^h\ 16^m\ 18^s.68$	$+19^\circ\ 42'\ 46''.3$

For the same epoch, the position which I have obtained by computation from THRAEN's elements of the orbit is only $1^s.31$ larger in right ascension and only $1''.1$ smaller in declination. These residuals are remarkably small, and show that THRAEN has reached most excellent results in his determination of the definitive elements of the orbit.

This comet was first seen as a nebulous body by MAX WOLF at Heidelberg, September 17, 1884, and its cometary nature was fully established by him on September 18th and 19th. He then notified the Strassburg Observatory of his discovery, and the first accurate position of the comet was obtained there on September 20th. On September 22d the comet was discovered independently at the Dun Echt Observatory by RALPH COPELAND, who detected it "as a gaseous body with the spectroscope." The